AUTHOR'S ABSTRACT OF THIS PAPER ISSUED BY
THE BIBLIOGRAPHIC SERVICE, MARCH 16, 1921.

OBSERVATIONS ON THE LARVÆ OF CORETHRA PUNCTIPENNIS SAY.

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INTRODUCTION.

As part of a general problem relating to the biological productivity of lakes, a quantitative survey of the bottom fauna in the deeper portions of Lake Mendota at Madison, Wisconsin, was made between the early part of May, 1916, and the middle of August, 1918. This survey included only the macroscopic forms, such as the insect larvæ, the Oligochæta, and the Mollusca. The investigation showed that the full-grown larvæ of *Corethra punctipennis* Say constitute the principal element of the bottom population in the daytime during the greater part of the year. For at least three quarters of the year, in fact, they not only far outnumber all of the other forms combined, but they also exceed them in total weight. The great abundance of these larvæ thus makes them a very important factor in the biological complex of the lake.

Samples of the bottom were obtained by means of a modified form of the Ekman dredge; the opening of this instrument covered an area of 473 square centimeters. The mud obtained in each haul of the dredge was washed through a gauze net having meshes fine enough to retain all of the macroscopic forms. The material secured by the net was transferred to a jar and was then taken to the laboratory where the various organisms were sorted out and enumerated in the living state. The average live and dry weights of the various forms were also obtained, as well as the percentage of ash.

Observations were made at five regular stations located in water having a depth of 20.5 meters to 23.5 meters. These stations were widely separated in order to secure a fair average of the density of the bottom population in the deeper portions of the

[1] Notes from the Biological Laboratory of the Wisconsin Geological and Natural History Survey No. XXI.

lake. The results obtained at only one of these stations, designated as Station II., are considered here, however, because the other four were not visited regularly during the winter months. From April to June inclusive, the number of larvæ found at Station II. was from 10 per cent. to 20 per cent. larger than the general average of the five stations during these months, but in August the general average was larger than the numbers at Station II. In the six sets of averages obtained for the last three months of the year in 1916 and 1917, three of the averages for Station II. were larger than the corresponding averages of the five stations and three were smaller. Thus, the numbers obtained at Station II. were somewhat larger than the general average for the deeper part of the lake as a whole during the first half of the year, but they were somewhat smaller from July to September and substantially the same from October to December.

Numerical Results.

The average number of *Corethra* larvæ per square meter of bottom is shown for the different months of the year in Table I. Large numbers of these larvæ live over winter; in fact they are

Table I.

The Number of Corethra Larvæ per Square Meter Obtained from the Mud in the Daytime at Station II. during the Different Months of the Year.

In all months except January and February the numbers represent averages of two to nine samples.

Year.	January.	February.	March.	April.	May.	June.
1916.....					17,300	4,550
1917.....	25,340	23,740	30,380	23,230	17,900	16,000
1918.....		23,440	20,160	18,940	18,170	9,430
Year.	**July.**	**August.**	**September.**	**October.**	**November.**	**December.**
1916.....	3,380		7,400	17,600	26,900	26,900
1917.....	6,080	800	3,740	11,500	17,700	24,800
1918.....	2,820	960				

more numerous from November to April than at any other time of the year. During this interval the numbers range from approximately 18,000 to 30,000 individuals per square meter. At

this time of the year there is no loss from pupation and the losses from other causes are not great enough to reduce the number of these larvæ very materially, so that the number remains uniformly high during this period of time.

The ice usually disappears from the lake during the first week in April and soon after this event the larvæ begin to pupate. As the temperature of the water rises, the rate of pupation increases so that an appreciable decrease in the number of larvæ is noted for the month of May. With the further advance of the season, pupation becomes still more common and this results in a very marked decrease in the number of *Corethra* larvæ in late June as in 1916 and in 1918, or in early July as in 1917. This decline in numbers continues until the minimum of the year is reached in August, more especially during the first half of this month. A minimum of 295 larvæ per square meter was noted at Station II. on August 2, 1917, while the average in March of this year was a little more than one hundred times as large. (See Table I.)

Small swarms of adults appear in May and in early June, but the great flights are correlated in time with waves of very active pupation in late June, in July, and in early August. Thus, enormous swarms appear from time to time during the latter period.

During late August and especially in September there is a slackening in the process of pupation and correlated with this is an increase in the number of larvæ. The increase is most marked during the second half of September and in early October, but the numbers do not reach the maximum point until November or December. The largest number of larvæ obtained in any of the samples was 33,800 individuals per square meter on December 21, 1917.

Pupæ were not noted in the samples of mud until about the middle of June, or at the beginning of the more active period of pupation; thereafter they appeared regularly until late August. A maximum of 2,890 pupæ per square meter was found on June 28, 1917, while the second in rank was 1,370 individuals per square meter on July 9, 1917.

Deposition and Development of Eggs.

According to Muttkowski the adults emerge at night, "beginning early in the evening and continuing through the night. In the morning, if the lake is quiet, the females can be seen on the surface, ovipositing through the surface film." Eggs deposited by females kept in insect cages sink to the bottom of the aquarium and experimental evidence indicates that those deposited at the surface of the lake also sink to the bottom. Mud from Station II. where the water is 23.5 meters deep and also from Station I., located in water 18.5 meters deep, was washed through a sieve with meshes fine enough to remove all of the larvæ; this sifted mud was then placed in aquaria. At the end of five days a dozen small *Corethra* larvæ had appeared in the material from Station II., while five small larvæ were noted in the other bottom material at the end of a week, thus showing that the mud from both stations contained eggs.

Eggs that were deposited by females kept in captivity hatched within forty-eight hours when the temperature of the laboratory ranged from 21° to 24° C. The temperature of the lower water in the deeper portions of the lake is much lower than this, however, and the eggs which reach the bottom in these areas probably do not develop so rapidly. The bottom temperature at Station II. in summer, for example, ranges from slightly more than 9° in some years to about 14° in other years. On the other hand, eggs deposited in water not exceeding five meters in depth are subject to temperatures of 20° to 25° in July and August so that they probably hatch about as promptly as those kept under laboratory conditions.

Another factor that may retard development in the deeper water is the absence of free oxygen. Usually all of the dissolved oxygen below a depth of 18 meters is used up by the middle of July, after which no oxygen is available in this region until October. Thus, all of the *Corethra* eggs which reach the bottom in water that is 18 meters deep or more during this period must develop under anaërobic conditions if they develop at all. This anaërobic stage covers the greater part of the most active reproductive period of this insect and approximately 30 per cent. of

the area of the lake lies within the 18 meter contour. For two or three weeks in August, in fact, a little more than half of the lake bottom is subject to anaërobic conditions. No attempt was made to ascertain the effect of this lack of oxygen on the development of the *Corethra* eggs. Many cocoons of the Oligochæt *Limnodrilus* were noted in the bottom material during this period, however, and the eggs in them seemed to be developing normally in the absence of oxygen. This fact suggests that the eggs of *Corethra* may also develop normally under anaërobic conditions.

The young *Corethra* larvæ were not noted in the series of net catches until the last week in June, though the eggs of the first adults each year undoubtedly hatch at an earlier date than this. They were found regularly in the net catches from the latter part of June to the first week in October.

Behavior.

In 1917 and 1918 net hauls were made regularly at three of the stations before the mud catch was taken in order to see if any of the full-grown larvæ occupied the water in the daytime, but the results were entirely negative. Some of these hauls were made as early as 8:30 A.M. and others as late as 4:30 P.M., so that these observations covered the chief portion of the day. It was found also that the full-grown larvæ deserted the water on cloudy days as well as on clear days.

A series of observations made at Station II. during the afternoon and evening of July 16, 1917, showed that the full-grown *Corethra* larvæ had not emerged from the mud by 7:30 P.M., or just about sunset. At 8:00 P.M., or half an hour after sunset, 133 larvæ and 88 pupæ per square meter of lake surface were found in the water. By 8:30 P.M., or one hour after sunset, these numbers had increased to 3,945 larvæ and 442 pupæ. At the latter hour the full-grown larvæ had reached the surface of the lake, thus showing a vertical migration of 23.5 meters during an interval of about one hour.

A similar set of observations was made in 1920 beginning at 5:45 P.M. on June 10 and continuing until 5:30 A.M. on June 11. On the former date sunset came at 7:36 P.M., standard time, and sunrise on the following day at 4:18 A.M. No *Co-*

rethra larvæ were obtained from the water on June 10 until 7:15 P.M., at which time a catch yielded 22 individuals per square meter of lake surface. Fifteen minutes later, or just a few minutes before sunset, this number had risen to 176 larvæ per square meter, and by 7:50 P.M., or about a quarter of an hour after sunset, the number was 1,576. At 7:36 P.M. the larvæ had not invaded the upper 10 meters of water, but they had ascended to the 10–15 meter stratum. They did not appear at the surface until about an hour and a quarter after sunset, so that the rate of upward migration was somewhat slower than that noted in 1917. Pupæ reached the surface at 9:00 P.M., or approximately an hour and a half after sunset. The largest number of both larvæ and pupæ found in the water during this set of observations was noted in a catch taken at 10:00 P.M.; of the former there were 4,730 individuals per square meter of lake surface and of the latter 287. By 11:00 P.M. the numbers had declined to 2,100 and 110 respectively; the numbers were substantially the same as these at 2:00 A.M. on June 11.

Larvæ were still found in the upper meter of water at 3:30 A.M., but they had disappeared from the upper 10 meters by 3:47 A.M. and only one individual was obtained in a catch taken from the 0–15 meter stratum at 3:50 A.M. Practically, then, they deserted the upper 15 meters of water during a period of about 20 minutes. It should be noted, also, that this downward migration was not due to direct sunlight since it took place at least half an hour before sunrise. The larvæ were still occupying the 15–23 meter stratum in considerable numbers, since a catch at 3:55 A.M. yielded 1,658 individuals per square meter in that region; the same catch contained 88 pupæ per square meter also. The number of larvæ in the lower water then gradually diminished, the last disappearing between 4:45 and 5:00 A.M. According to these results, then, the full-grown *Corethra* larvæ enter the bottom mud by the end of the first half hour after sunrise and they remain there until about sunset.

Samples of mud taken at 6:00 and at 7:00 P.M. on June 10, 1920, yielded an average of 2,720 larvæ and 55 pupæ per square meter of bottom; as a result of the migration into the water these numbers had declined to 1,400 larvæ and 22 pupæ per square

meter at 8:00 P.M., while the samples obtained during the next three hours yielded from 1,600 to 2,100 larvæ. The latter number was also found at 3:00 A.M., but it rose to 2,665 at 4:00 A.M. and to slightly more than 3,000 per square meter at 5:00 A.M. Thus the mud contained from one half to two thirds as many larvæ at night as were found there in the daytime.

For a certain period after they hatch out, the behavior of the young larvæ is very different in the daytime from that of the full-grown individuals; that is, the former occupy the lower water during the daylight hours instead of the mud, being found in the lower part of the mesolimnion and in the hypolimnion. The young larvæ migrate into the upper water at night just as the full-grown ones do. It has not been definitely determined just how long this difference in behavior lasts; only rarely was an individual found in the mud which was estimated to be only one third as large as a full-grown larva and frequently individuals were obtained from the water which were recorded as half grown. Thus, it appears that the young larvæ inhabit the lower water in the daytime instead of the mud until they are approximately one third grown, or perhaps a little larger. Muttkowski states that the larval period lasts from six to seven weeks in the summer broods; on this basis it may be estimated that the difference in behavior between the young and full-grown larvæ continues for the first ten days or two weeks of the larval period.

A series of catches was made with a plankton trap on August 2, 1917, for the purpose of ascertaining the vertical distribution of the small larvæ. The results are shown in Table II. No larvæ were found in the upper 8 meters, but they appeared at 10 meters and at greater depths. The maximum number, 489 individuals per cubic meter of water, was obtained at a depth of 18 meters, which was about the middle of the hypolimnion. Somewhat more than 88 per cent. of the total number of individuals occupied the 15–20 meter stratum.

Some results obtained on Devils Lake, Wisconsin, show that the behavior of the full-grown larvæ of *Corethra plumicornis* Fabricius[1] differs in the daytime from that of *C. punctipennis* in

[1] Dr. J. R. Malloch kindly identified this larva.

Table II.

The Number of Young Corethra Larvæ per Cubic Meter of Water at Different Depths of Lake Mendota on August 2, 1917.

Those obtained at 10 meters and 12 meters were recorded as very small and for the other depths the individuals were estimated to be from a quarter to a third as large as full grown larvæ.

Depth in Meters.	Temperature, Degrees C.	Number of Larvæ per Cubic Meter.
8	19.8	0
10	17.4	44
12	16.0	67
15	14.5	200
18	13.6	489
20	13.5	311
23	13.3	22

Lake Mendota. In the former lake two net catches on May 25, 1917, which were made in the deepest water, namely, 14 meters, gave an average of 422 full-grown *C. plumicornis* larvæ per square meter of surface, while two hauls of mud at the same place yielded an average of 433 individuals per square meter. That is, these larvæ were substantially equally divided between the water and the mud at about 10:00 A.M. on a bright morning when the water was so transparent that a white disc 10 centimeters in diameter did not disappear from view until it reached a depth of 8.6 meters. In other words, the day distribution of the larvæ of *C. plumicornis* was practically the same in Devils Lake as the nocturnal distribution of the larvæ of *C. punctipennis* in Lake Mendota.

While the larvæ of *Corethra punctipennis* give a prompt negative reaction to light, yet it hardly seems probable that their extensive depth migration in Lake Mendota, even including a descent into the mud, is a simple light phenomenon. The transparency of the water is usually low in summer; a white disc 10 centimeters in diameter generally disappears from view at a depth of two meters to about four meters at this season of the year, which indicates that the light is cut off rather rapidly by the upper strata of water. On the morning of June 11, 1920, for example, the disc reading was 4.25 meters. A pyrlimnimeter has been used to determine the rate at which the sun's energy is cut off by the upper strata of the lake. The results obtained with this instru-

ment indicate that the intensity of the illumination at a depth of 23 meters on a clear day, between 11:00 A.M. and 1:00 P.M., is about equal to that produced by full moonlight at the surface of the lake. During the early forenoon and the late afternoon, as well as on cloudy days, the illumination is much smaller than this. For some time before sunset, the bottom stratum must be substantially in total darkness, yet the observations show that the emergence of the larvæ from the mud is very closely correlated in time with the setting of the sun.

Not only does the illumination in the bottom water become very small in the late afternoon, but there is a further protection from light afforded by the bottom ooze in which the larvæ remain concealed during the day. To what depth the larvæ penetrate the loose mud is not known, but in the laboratory they readily burrow down to a depth of a centimeter or more. The dim light which reaches the bottom in the deeper portions of the lake can penetrate the ooze only to a very slight extent at most, even during the brightest part of the day, and this raises the very interesting question as to what stimulus causes the larvæ and pupæ to emerge from the mud so promptly and regularly about the time of sunset. No definite data bearing on this point have yet been obtained.

These larvæ are eaten with avidity by many fishes and their habit of occupying the mud in the daytime may thus serve a very important purpose from the standpoint of protection from such enemies. A further protection is afforded by the disappearance of the dissolved oxygen in the hypolimnion. Usually by the first of August very little free oxygen remains in this stratum, which makes the lower water unfit for the permanent occupation of the larger forms which prey upon these larvæ. In spite of the lack of oxygen, however, Pearse and Achtenberg found that the yellow perch—*Perca flavescens* (Mitchill)—invades the lower water and feeds upon these larvæ. While these fish survive for a period of two hours in water that contains no dissolved oxygen, these authors state that it is doubtful whether a perch is able to feed for more than a few minutes at a time under such conditions. It seems probable, therefore, that the *Corethra* larvæ are not eaten as freely as they might be if anaërobic conditions did not

prevail in the lower strata of the deeper water. Also, the absence of dissolved oxygen in the hypolimnion serves as a protection to the young larvæ which occupy this region in the daytime for a certain period after they hatch out.

Number in Shallower Water.

The larvæ of *Corethra punctipennis* show a decided preference for the deepest portion of Lake Mendota. In the daytime, they are much more abundant in the mud where the water reaches a depth of 20 meters or more than they are in the shallower areas. It was found that the average number of larvæ within the area bounded by the 20 meter contour line was more than three times as large as the average for the region lying between the 8 meter and the 20 meter contours, while the number obtained in areas where the water did not exceed five meters in depth was practically negligible.

Some three hundred samples were taken in series which extended from the shallow water to the deep water; that is, from a depth of 8 meters or 10 meters down to a depth of 20 meters. The results of four sets of these observations are shown in Table III. It will be noted that there was a marked increase in the

Table III.

The Number of Corethra Larvæ per Square Meter of Bottom at Different Depths in Four Sets of Observations which were Made in 1917.

Date.	Depth in Meters.	Number.	Date.	Depth in Meters.	Number.
May 15........	10.5	820	September 24 ..	10	110
	12.5	1,600		12	250
	15.5	4,640		15	5,500
	18	4,810		18	7,490
	20	7,800		20	13,380
June 22........	10	100	October 24.....	12	85
	12	85		15	2,740
	15	1,080		18	11,650
	18.5	1,710		20	15,930
	20.5	3,610			

number of larvæ correlated with the increase in the depth of the water. On May 15, for example, the sample taken at 15 meters yielded about six times as many as the one at 10 meters, while

that at 20 meters gave nearly ten times as many as the latter. On September 24, the differences were fiftyfold and more than a hundredfold, respectively, and on October 24 the number was nearly two hundred times as large at 20 meters as at 12 meters.

Just how these larvæ are able to constantly maintain such a marked difference in numbers in favor of the deep water is a puzzling question. Their method of locomotion would not lead one to expect them to travel very far of their own accord should they reach the shallow areas, yet it seems probable that many of them are carried into the shallow water by the currents when they migrate into the upper strata at night. This would be true especially on windy nights. Table III. shows that a very small number of larvæ is found at 10 meters as compared with the deep water and 39 per cent. of the area of the lake lies outside the 10 meter contour line. The number is usually not much larger at 12 meters than at 10 meters and the former divides the area of the lake approximately into halves. The outer or shallower half of the lake, then, is very sparsely populated by these larvæ, but it is not clear just how the number is kept so small in comparison with the inner or deeper half of the lake.

In a large proportion of the former area the bottom does not consist of material in which the larvæ can readily conceal themselves in the daytime, being composed of sand, gravel, and rock, so that the tendency would be to avoid these areas. On the other hand, the larvæ are no more abundant in the shallow portions of protected bays where a muddy bottom suitable for concealment is found at a depth of only 5 meters or 6 meters. The difference can scarcely be attributed to a proportionally unequal distribution of eggs between the two regions because very large numbers of egg bearing females are found over the shallow water as well as along the shore; it seems probable, therefore, that enormous numbers of eggs are deposited in the shallow areas.

When the larvæ migrate into the upper strata of the lake at night, the direct currents tend to carry them into the shallow water, but the return currents, on the other hand, will aid more or less in bringing them back to the deep water. Apparently the chief factors governing the distribution of the *Corethra* larvæ

between the shallow half and the deep half of the lake are (1) an active migration, (2) the currents—direct currents on the windward side of the lake and return currents on the leeward side, (3) a relatively greater loss in the shallow water due to predatory enemies.

Number in Other Lakes.

For purposes of comparison similar quantitative studies of the bottom population were made regularly in Lake Monona and in Lake Waubesa during 1917. The former is only one kilometer from Lake Mendota and has nearly as great a maximum depth, namely, 22.5 meters. Lake Waubesa lies about seven kilometers southeast of Lake Mendota, but it is a much shallower body of water, having a maximum depth of only a little more than 11 meters. In Lake Monona only about one tenth as many *Corethra* larvæ were found as at corresponding depths and times in Lake Mendota; in some instances the difference was more than a hundredfold in favor of the latter lake. In the deepest part of Lake Waubesa the number varied from about the same as that at 11 meters in Lake Mendota to only a third or a quarter as many; but the deeper water of Lake Mendota yielded from forty to a hundred times as many larve as the deepest portion of Lake Waubesa. Bottom material has been obtained from about a dozen other Wisconsin lakes and in all of them the *Corethra* population has been relatively small, which seems to indicate that Lake Mendota offers a particularly favorable habitat for these larvæ.

Gravimetric Results.

Between June, 1916, and April, 1917, more than fourteen thousand larvæ of *Corethra punctipennis* were picked out of the material collected in Lake Mendota and they were dried for the purpose of making a chemical analysis of them. The average amount of dry matter per individual for this number was 0.251 milligram. The average weight was also determined for eleven other lots of larvæ containing from 100 to 300 individuals each. These averages ranged from a maximum of 0.311 milligram per larva, dry matter, in June to a minimum of 0.182 milligram in early September. The results of these weighings are shown in

Table IV. The higher average of dry matter in the June material may be due to a larger proportion of chitin in the larvæ just before they pupate. In August and early September the average size of the larvæ seems to be smaller than that of the winter brood and this is confirmed by the weights. At the height of the pupating season the summer larvæ pupate when they are distinctly smaller than the individuals which live over winter. The live weights of the smaller lots were also determined, as shown in Table IV., and they indicate that about 91 per cent. of the living animal consists of water.

The live weight of the June pupæ was only about 11 per cent. larger than that of the June larvæ, but the dry weight of the former was nearly twice as large as that of the latter. (See Table IV.) This marked difference in the dry weight was probably due to the presence of a larger amount of chitin in the pupa.

TABLE IV.

THE AVERAGE WEIGHT OF A SINGLE INDIVIDUAL OF CORETHRA PUNCTIPENNIS IN MILLIGRAMS, TOGETHER WITH THE PERCENTAGES OF WATER AND OF ASH.

Form.	Month.	Live Weight in Milligrams.	Dry Weight in Milligrams,	Per Cent. of Water.	Per Cent. of Ash.
Larva....	February...	3.06	0.250	91.72	7.06
	May.......	3.30	0.264	92.12	7.96
	June.......	3.15	0.311	89.13	7.33
	September..	2.57	0.182	92.93	9.53
	October....	2.83	0.264	90.66	8.62
	November..	3.20	0.285	91.03	8.10
Pupa.....	June.......	3.52	0.574	83.71	5.80
Adult.....	June.......	0.75	0.427	43.32	5.89

The adults yielded a much smaller live weight than either the larvæ or the pupæ because they possessed a much smaller proportion of water. Their dry weight was greater than that of the larvæ but smaller than that of the pupæ. The adults used for this weight were obtained from a large swarm on June 29, 1918, when pupation was very active, but there was no means of ascertaining their age; their weight probably decreases somewhat with age, and they live for a period of three to five days.

The ash of the larvæ varied from a minimum of about 7 per

cent. of the dry weight to a maximum of 9.5 per cent., the former being noted in February and the latter in September. The pupæ and adults yielded substantially the same percentages of ash, but these percentages were much smaller than in the larvæ.

There is more or less overlapping of the summer broods, which makes it difficult to estimate the number of larvæ produced during this season, but the winter crop of larvæ may be estimated with some degree of accuracy. In this investigation twenty-two samples of mud were obtained at the five regular stations in deep water during the month of November and they yielded an average of 17,350 *Corethra* larvæ per square meter of bottom. Five samples were secured in December also, and they gave an average of 21,900 individuals per square meter; but four of these samples were taken at Station II. which usually gave a larger yield than the other four stations. According to these figures, the early winter population of *Corethra* larvæ within the 20 meter contour may be conservatively estimated at 18,000 individuals per square meter. Between October and May the live weight averaged 3.1 milligrams per larva and the dry weight 0.266 milligram. Applying these weights to the above population gives a live weight of 55.8 grams per square meter, or 558 kilograms per hectare, which is equivalent to 497 pounds per acre, and a dry weight of 4.8 grams per square meter, or 48 kilograms per hectare, equivalent to 42.7 pounds per acre.

Muttkowski states that there may be two generations of summer larvæ in addition to the winter generation; but, since the former average somewhat smaller in size than the latter, the total weight of the summer broods is probably not greatly in excess of that of the winter brood. That is, a live weight of 1,200 kilograms per hectare (1,070 pounds per acre) would be a conservative estimate for the total annual production of *Corethra* larvæ in the deeper part of Lake Mendota; on this basis the dry weight would amount to somewhat more than 100 kilograms per hectare, or approximately 90 pounds per acre. These figures apply only to that portion of the lake which lies within the 20 meter contour line, since the larvæ are found in very much smaller numbers in the shallower water.

The 20 meter contour encloses an area of 664 hectares which would give an annual crop of larvæ amounting to substantially 797 metric tons, live weight, for this portion of the lake, or a dry weight of about 67 metric tons. The live weight of all other macroscopic inhabitants of this area was 92.3 metric tons and their dry weight was about 19 metric tons.

As previously indicated, the population of *Corethra* larvæ in the region between 8 meters and 20 meters averaged about one third as large per unit area as that in the deeper water. In order not to overestimate the annual production of the shallower water, the area lying between the shoreline and a depth of 10 meters may be omitted from the calculation since the number of larvæ found in this region is small; in addition, also, the average between the 10 meter and 20 meter contours, comprising an area of 1,738 hectares, may be reckoned as one quarter instead of one third as large as that of the deep water. On this basis the live weight becomes 300 kilograms per hectare and the dry weight 25 kilograms, thus making the annual crop of *Corethra* larvæ in this portion of the lake a little more than 521 metric tons, live weight, or about 43 metric tons of dry material. These results combined with those obtained for the deep water area give a total annual production of 1,318 metric tons of living larvæ which would yield 110 metric tons of dry material.

Chemical Results.

The results of the chemical analysis of the larvæ are shown in Table V. and they are stated in percentages of the dry weight.

Table V.

Results of the Chemical Analysis of the Larvæ of Corethra punctipennis Stated in Percentages of the Dry Weight.

Nitrogen.	Crude Protein ($N \times 6.25$.)	Ether Extract (Fat).	Crude Fiber (Chitin)	Per Cent. Ash,
10.74	67.12	9.45	6.15	7.96

The percentage of nitrogen is notably high, which means a correspondingly large proportion of crude protein. The percentage

given in the table does not include the nitrogen in the crude fiber (chitin) which amounted to 0.46 per cent. In comparison with this the larvæ of *Chironomus tentans* yielded a much smaller percentage of nitrogen, namely, 7.36 per cent.

The larvæ yielded a fairly large amount of fat (ether extract), namely 9.45 per cent. of the dry sample. Together the crude protein and the fat constituted more than 76 per cent. of the dry material. From the standpoint of quality, this large proportion of these two excellent food materials gives the larva of *Corethra punctipennis* a very high rank as a source of food for other organisms.

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